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THE ATOMIC ENERGY CONTROL BOARD CRITERIA FOR IDENTIFICATION AND EVALUATION OF FIRE HAZARDS IN NUCLEAR POWER STATIONS VOLUME 2 - CRITERIA

by

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ATOMIC ENERGY CONTROL BOARD
CRITERIA FOR IDENTIFICATION AND EVALUATION OF FIRE HAZARDS IN NUCLEAR POWER STATIONS
VOLUME 2 - CRITERIA

ABSTRACT

This report presents criteria for the identification and evaluation of fire hazards in nuclear power stations. The report presents criteria that are consistent with the existing regulatory approach in Canada, and outlines engineering tools and analytical techniques currently available to deterministically analyse fire. The criteria presented cover the topics which should be included in a fire hazard analysis and provide details of each topic so that the accuracy of an analysis may be evaluated.

RÉSUMÉ

Ce rapport présente des critères pour désigner et évaluer les dangers d'incendie dans les centrales nucléaires. Ces critères sont conformes à l'approche réglementaire actuelle de la CCEA au Canada et traitent des points à inclure dans l'analyse des dangers d'incendie. Des détails sur chaque point sont fournis pour permettre d'évaluer la qualité de l'analyse. Le rapport indique aussi les outils et les techniques actuellement disponibles pour analyser les dangers d'incendie de façon déterministe.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication and neither the Board nor the author assumes liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

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DEFINITIONS

Active Control Measure - Equipment or systems which sense fire conditions and initiate action to bring about its control.

Administrative Control Measure - A procedure or policy established by the plant administration to reduce the potential for fire hazards or to maintain the reliability of safety systems.

Analysis - An examination of a complex, its elements and their relationship.

Combustible Liquid - A liquid having a flash point at or above 37.8°C.

Combustion Products - Gases, solid particulates, liquid particulates, and residues evolved or remaining from combustion. In general, the products include fire gases, flames, heat ,smoke, ash and other residue.

Common Cause Effects - Common cause effects are effects manifested in more than one piece of equipment or structure by the same cause (AECB Consultative Document C-6 classifies fire as a common cause effect).

Conduction - Transfer of heat, usually through a solid or liquid, induced by a temperature gradient.

Convection - Transfer of heat by the motion of a fluid under the influence of differences in density and gravity.

Cross-Link Effects - Cross-link effects are those effects resulting from a lack of independence or separation, either physical or functional, between systems or components or operating actions.

Descriptor - An expression used to describe or identify.

Design Basis Fire - The fire resulting from the worst plausible case fire conditions.

Exposed - A person or thing of value which is vulnerable to damage by a fire.

Extinction - The termination of combustion.

Fire - Unwanted combustion.

Fire Hazard - Potential for harm from fire.

Fire Hazard Analysis - An examination of the potential sources of unwanted combustion, their components; and their ability to cause harm to safety functions in a nuclear power plant.

Fire Severity - the quantification of fire by one or more descriptors.

Fire Signature - Any product of a fire which changes the ambient conditions.

Fire Zone - A fire zone is that area of the plant which is distinguished from other areas for fire analysis purposes.

Flame - The luminous by-products of combustion.

Flammable Liquid - A liquid having a flash point below 37.8°C and having a vapour pressure not exceeding 275.8 KPa (absolute) at 37.8°C.

Flashover - A stage in the development of a contained fire in which all exposed surfaces reach ignition temperature more or less simultaneously.

Flash Point - The minimum temperature at which a liquid within a container gives off vapour in sufficient concentration to form an ignitable mixture with air near the surface of the liquid.

Hazard - A source of danger or a potential for harm. (In the context of nuclear power plants; hazard is a source of danger or potential for harm to the safe operation of a nuclear power plant).

Ignition Energy - The quantity of heat or energy that must be applied to a substance to cause sustained combustion.

Passive Control Measure - A feature or component of a facility which by its existence will control fire growth.

Plume - The convective currents and smoke emanating from combustion.

Radiation - Transfer of energy, including heat, by electromagnetic waves.

Radiation View Factor - The fraction of energy leaving a flame (or hot substance) which reaches an exposed item. Discussion of radiation view factor or shape factor can be found in most texts on Heat Transfer.

Risk - Likelihood that a hazard will occur.

Signature - See Fire Signature

Smoke - A visible or nonvisible, nonluminous, airborne suspension of particles, originating from combustion.

Vital Equipment - Safety systems and safety related systems as used in the context of nuclear related safety.

ATOMIC ENERGY CONTROL BOARD
CRITERIA FOR IDENTIFICATION AND
EVALUATION OF FIRE HAZARDS IN
NUCLEAR POWER STATIONS
VOLUME 2 - CRITERIA

A. INTRODUCTION

The Atomic Energy Control Board requires licensees to verify the safety of plant design by performing safety analyses. These analyses are included in a safety analysis report which is submitted to the AECB for review. A consideration which must be incorporated in these analyses is the impact of unwanted fires. The plant safety analyses, therefore, must address the hazard unwanted fires present to safe plant operation. This portion of the overall plant safety analyses is called the plant's "Fire Hazard Analysis".

The fire hazard analysis is intended to establish that the potential for unwanted fires to harm or endanger a Candu nuclear plant's safety functions is very small. It is the intent of this report to present criteria for the AECB's use in reviewing the fire hazard analysis portion of a licensee's safety analysis report.

1. Fire Hazard Analysis Overview

Fire, for the purposes of this report, is defined as unwanted combustion and consequently excludes fires in boilers or heaters where combustion is controlled.

A "hazard" is a source of danger or the potential for harm. For the safe operation of the nuclear systems at a Candu power plant, a hazard will be considered as the potential to harm a safety system or safety related function of the plant.

Fire hazard analysis is the examination of the potential for fire to damage safety or safety related systems in the plant. The analysis must identify each potential source of fire and determine if its severity will cause a safety concern. For example, reactor control wiring may run in a cable tray above some combustible material. The analysis must establish if the maximum temperature created at the cable tray elevation by the burning of the combustible material will be greater than the maximum temperature which the control wiring can safely withstand. Or, stated in the form of an equation, is a descriptor of the fire's severity (eg. maximum temperature) greater than some descriptor of the exposed's vulnerability to damage? In an abbreviated form, is

FIRE DESCRIPTOR > EXPOSED DESCRIPTOR ?

2. Project Objective

The objective of this project is to develop for the Atomic Energy Control Board review criteria to assist in evaluating a fire hazard analysis. This report will examine the conditions and engineering tools and analytical techniques presently available to establish and quantify the sources of fire; the elements which control its severity and the potential for fire to damage safety related functions in a Candu plant.

B. CRITERIA FOR EVALUATING A FIRE HAZARD ANALYSIS REPORT

The objective of a fire hazard analysis report is to demonstrate that fires (and fire control measures) will not harm the safe operation of a nuclear power plant. The following material summarizes the topics which should be covered in a fire hazard analysis report. Details are also provided to assist in judging the quality of this coverage.

An analysis of the potential impact of fire on nuclear plant safety requires two main ingredients. Firstly, a methodology for the analysis should be provided and secondly, detailed evaluations for case studies should be developed.

1. Analysis Methodology

A fire hazard analysis should outline a methodology for achieving the report objectives. This should include a clear definition of the objectives and a listing of the case studies required to demonstrate that the objectives are met.

1.1 Report Objectives

The fire hazard analysis should provide clear measurable objectives for the report. These objectives would be expected to address nuclear concerns in terms of the ability of a plant to shutdown its reactor, remove its decay heat, and monitor its safety status under fire conditions.

Once the report objectives are defined, the means for demonstrating how the objectives will be met should be stipulated. It is recognized that various approaches could be used in a fire hazard analysis and the report should outline the approach it will follow. This is a necessary topic to cover as the fire hazard analysis must integrate with other safety analyses. A comprehensive coverage of this topic should show that the analysis methodology will:

1. conduct a fire hazard analysis of events, evaluated in other safety analyses, which could result in fire (eg. turbine breakup, massive failure of pump casing of a reactor main circulating pump, failure of all mechanical seals on a reactor main coolant pump, etc).
2. evaluate the potential for fire damage to exposed items identified by other safety analyses as critical to plant safety.
3. provide a synthesis of each case study with the safety analysis which called for the fire study to be done.

1.2 Listing Case Studies

In order to show that the objectives will be met, cases with postulated hazards must be evaluated. The source of these hazards may be fire, a fire control measure or both. To provide confidence of a comprehensive study, the report should demonstrate a systematic approach which, when establishing the list of cases to be evaluated, covers all aspects of the plant.

1.2.1 Systematic Approach To Covering All Aspects of the Plant

A fire hazard analysis, to be comprehensive, should demonstrate that: all areas of the plant have been considered, all potential sources of fire-related damage have been evaluated, and all vulnerable items have been considered.

1.2.1.1 Plant Areas

A detailed fire analysis will not necessarily be required for all areas of a plant. However, the report should demonstrate that all areas have been considered and justification for excluding specific plant areas should be documented. A fire hazard exists where a source of danger (eg. fire) and an exposed item of concern (eg. emergency power system) can impact each other. Elimination of a plant area from detailed evaluation will require demonstrating that one of the two items (source of danger or exposed) is not present. Demonstrating this requires that areas

of a plant be clearly defined by a boundary. This boundary could be real (eg. wall) or intangible (eg. a column line).

Depending on the analysis approach used, the analysis report should demonstrate that it has considered:

1. the potential for an exposed item of concern to be harmed by a source of fire-related damage in an adjacent area, or a space indirectly connected to or communicating with it, (eg. Figure A-1 and Figure A-2 of Appendix A respectively).
2. the potential for a source of danger to harm an exposed item of concern in the same area, (eg. Figure A-3 of Appendix A).

1.2.1.2 Sources of Fire-Related Damage

There are two main sources of fire-related damage which should be covered in the analysis report. One is fire and its by-products. The second is the possible damage arising from fire control systems or measures. The fire hazard analysis report should cover both topics.

a. Fire

For a fire to occur, four conditions of combustion must exist: fuel must be present, energy (in the form of an ignition source) must be present, an oxidizing agent must be present, and an uninhibited chain reaction must be possible.[1] As the last two conditions are normally satisfied, identifying the potential for fire will normally involve demonstrating that consideration has been given to the presence of fuel and ignition sources (energy) in each area.[2]

The fire hazard analysis report's coverage for identifying fuels and ignition sources should be on the basis of historical loss data, material properties, or formalized evaluations (eg. failure mode and effects analysis). Details on these methods for identifying potential fuels and ignition sources are summarized

in section C of Volume 1 of this report.

The coverage of potentials for fire should show that consideration has been given to fixed and possible transient fuels. Fixed fuels would include combustible gases, liquids and solids which could be part of:

1. the structure (walls, interior finish, etc)
2. equipment (electrical equipment, pumps, cables, etc), and
3. furnishings (racks, storage, chairs, tables, books, etc).

Transient fuels which might be expected in different areas could include:

1. maintenance items (eg. cleaning solvents, broom, waste containers, etc)
2. temporary staging (eg. wood scaffolds, forms, etc) and
3. renovation materials (eg. tool cribs, wood storage crates, contractor sheds, etc).

Coverage of discussions on energy for ignition, should also include fixed and transient sources. Fixed ignition sources could include:

1. electrical equipment (eg. motors, switchgear, transformers, etc.)
2. hot machinery (eg. diesel generator, steam pipes, heat transport pipes, etc.)
3. open flames (eg. burner of a boiler)

Transient ignition sources could result from:

1. maintenance activities (eg. welding sparks, sparks from grinding operations, etc.)
2. personnel activities (eg. smoking)

b. Control Measures

In developing the fire hazard analysis methodology, the potential for a fire hazard control measure to create a damaging condition should be reviewed. This review should cover all control measures which could be used in an area. Some control measures, such as water-based extinguishing systems, will change the environment of the area they are protecting when they operate. This change could result in damage to certain exposed items of concern. Accordingly this topic should be discussed.

Discussions of this topic should identify which control measures could result in a chemical or physical change to the environment of a space under consideration. This can be established on the basis of the system operational principles as covered in Section F of Volume 1 of this report. The changes of interest are those which could impact an exposed item of interest. Discussion should include anticipated as well as accidental operations.

1.2.1.3 Exposed Items of Interest

For a fire hazard to exist there must be the potential to harm some item of interest. The exposed item of interest may be a fire zone boundary (as shown in Figure A-1 and A-2 of Appendix A) or a particular piece of equipment or a person (as shown in Figure A-3 of Appendix A), depending on the objectives and the analysis approach used. In identifying the exposeds, therefore, a fire hazard analyst should summarize the analysis approach (or approaches) being used and show that a thorough review of potential exposed items has been made. This review should include appropriate referenes to the source of data on an exposed as summarized in Section D of Volume 1 of this report. This is of particular interest where a fire hazard analysis is being conducted for an exposed item identified as critical to plant safety by other safety analyses.

1.2.2 Defendable List

A fire hazard analysis report should include a defendable list of cases requiring detailed evaluation. To defend a list of cases requiring evaluation it should be shown that a systematic methodology has been used in the selection process. It should also be shown that consideration has been given to fire events involving both large quantities of combustibles and small quantities of combustibles either of which could have a harmful impact on an exposed. This may involve evaluating fires initiating adjacent to an exposed, as well as, fires initiating in an exposed (eg. fire in critical electrical switchgear or cables).

The defense of the list of events to be evaluated should be demonstrated or supported on the basis of:

1. the frequency of an event (this may be demonstrated by the likelihood of ignition of the combustibles in a particular area)
2. the existence or absence of a potential fire-related damaging agent (either in or outside the immediate area of an exposed), or
3. the existence or absence of an exposed.

Where it has been shown that a detailed evaluation of a specific area is not required, it may be necessary to demonstrate that administrative control measures exist to ensure the conditions stipulated in the analysis report will continue to exist during the operating life of the plant. It should also be demonstrated that audit procedures exist to monitor appropriate areas to ensure conditions are maintained. The administrative controls required to demonstrate that plant conditions are maintained are summarized in Volume 1 Section F of this report.

2. Detailed Evaluation For Case Studies

Each case identified as requiring detailed evaluation in the fire hazard analysis report should quantify the impact of fire-related damaging agents on exposed items of concern. This will involve quantifying potential damaging agents, quantifying the exposed, and providing a synthesis of these quantifications.

2.1 Damaging Agents

There are two types of fire-related damaging agents which should be covered in a fire hazard analysis report: the fire itself, and fire control measures. The events resulting from the chosen cases for evaluation should cover all significant concerns that are necessary to show adequate protection from both sources of damaging agents. For example, if a fire can initiate a fire control measure, the analysis must consider both fire damage (eg. damage due to high temperature) and damage resulting from a control measure (eg. damage resulting from manual fire fighting).

2.1.1 Fire as a Source of Damaging Agents

To quantify fire as a potential source of damage the fire hazard analysis should provide a defendable methodology in the selection of an appropriate descriptor for fire and the calculation (quantification) of fire severity.

2.1.1.1 Selection of Descriptor

Fire can be described in terms of its by-products. Its by-products can be categorized under three main headings: energy release by-products, aerosol release by-products, and gas release by-products. These by-products are referred to as signatures and are specified by specific quantifiable descriptors for establishing fire severity. For example, the temperature of a fire could be a descriptor of the energy release signature. A summary of descriptors used to establish fire severity is included in section B-2 of Volume 1 of this report.

In selecting a descriptor, the analyst should include in his review of this topic three main items: the analysis approach, the exposed of interest, and a synthesis of the exposed's vulnerability to damage by various possible fire descriptors. The analysis approach should summarize the type of analysis being performed (eg. potential for harm to exposed from a fire in adjacent area as shown in Figure A-1). The type of analysis will indicate possible exposed items of concern. The exposed items should be further defined in terms of vulnerability to damage from fire. Based on the type of analysis and exposed of interest, a synthesis can be made of the chosen fire descriptors with the appropriate descriptors of the exposeds vulnerability. This synthesis should determine whether the exposed would or would not be significantly damaged.

2.1.1.2 Quantify Severity

Quantifying fire severity involves calculating values for the descriptor(s) chosen to be appropriate for the event under consideration. Fire severity, therefore, is a measure of a fire's development in terms of a descriptor or specific descriptors.

In quantifying a specific fire's severity, a fire hazard analysis should demonstrate that worst plausible conditions are considered. The topics which should be covered are: the fire area, the fuel(s) involved, the analytical techniques used, and the effect of the control measures in place.

(a) Area Conditions

Since area conditions and environmental variables will affect the air flow to a fire and the heat loss to surroundings, the coverage of this topic should include a definition of these conditions. The geometry of the fire area should be defined in terms of dimensions and fire location relative to an exposed. The construction of the walls, ceiling and floor in the area

should be defined. The analysis should also establish the openings (eg. door, windows) in the enclosure, as well as any forced ventilation into the space. The various area conditions which could affect fire growth are discussed in Drysdale's book[3] on fire dynamics and in Volume 1 Section E of this report.

(b) Fuel

A fire hazard analysis should establish what fuels (both permanent and transient) could be present. Details of the various fuels' properties and quantity should be covered. The details should be consistent with those required for the analytical technique to be used in an evaluation. Fire-related fuel properties which may be needed might include: rate of heat release, heat of combustion, species (eg. carbon monoxide) generation rate, etc. These properties are discussed in Volume 1 Section C of this report.

The quantity and form of the fuel should also be discussed along with the arrangement of various fuel items in the area being evaluated. In discussion of the arrangement of the fuel in an area, the analysis report should substantiate the likelihood of all combustibles in an area being involved in combustion. This substantiation will depend in part on the analytical technique(s) used.

(c) Analytical Technique

A fire hazard analysis report should demonstrate that the analytical technique used to quantify fire severity is appropriate and that it provides a conservative result.

The coverage of this topic should correlate the analytical technique's suitability for the case being evaluated in terms of:

1. the descriptor being used (eg. the technique must have a correlation from full scale fire tests for the descriptor

used. The references for the various analytical techniques described in Volume 1 Section E of this report describe the experimental bases for each technique).

2. the area conditions (eg. the technique should have been correlated to fire tests which simulate the physical conditions being analyzed. Details on these correlations are included in the discussion of analytical techniques included in this report, Volume 1 Section E).
3. the fuel type(s) (eg. does appropriate input data exist for the fuels of interest. More detailed information exists on the input requirements for each technique in Volume 1 Section E of this report).
4. the technique's limitations (eg. some techniques such as ASET are not valid for room fire temperatures in excess of 350-400^{o}C. Limitations discussed in Volume 1 Section E should be compared to conditions being evaluated).

The fire hazard analysis should also cover the conservativeness of the analytical technique by listing all assumptions and conducting a sensitivity analysis on the input variables.

(d) Control Measure's Ability to Mitigate the Effect of the Fire

In quantifying fire severity the fire hazard analysis should evaluate the response of control measures in limiting fire growth and preventing fire spread. The coverage of this topic should include a review of the effectiveness, completeness and reliability of each control measure.

The effectiveness of a control measure should be established by summarizing the method it uses to achieve its fire safety objective. For administrative control measures this would involve establishing how a particular administrative policy or procedure would prevent fire from occurring or maintain stipulated safety conditions. Demonstrating the effectiveness of

the control measure would involve inclusion of documented inspections which report violations of a control measure and evidence of regular audits to confirm that an administrative control measure is achieving its objective.

The effectiveness of active and passive control measures should also be established by summarizing the method used to achieve a fire safety objective. This effectiveness can be established by covering:

1. how the control measure responds to fire,
2. the method by which the measure controls fire,
3. the point at which the measure responds to a specific fire's development (eg. a quantification of the point in time at which a control measure responds), and
4. the ability of a measure to control a specific fire (eg. a quantification of a measure's ability to control a specific fire, or in the case of manual fire suppression evidence should be provided of training in control of the specific fire of interest).

Support for establishing a control measure's effectiveness can be demonstrated by:

1. test (eg. fire wall passing ULC S101[4]; fire extinguisher passing ULC CAN4-S508[5] or other tests referenced in Volume 1 Section F of this report).
2. calculation (eg. fire wall having resistance required as calculated using methods described in report Volume 1 Section F).
3. experience contained in loss records and standards (Details of standards and loss records for various control measures are included in report Volume 1 Section F (for example, NFPA Standard No. 13[6] requires sprinkler density of 4.1 L per min/m^2 over 139 m^2 for light hazard (office occupancy)).

The completeness of a control measure can be demonstrated by showing that it can achieve its function of preventing fire spread or extinguishing fire. For fire barriers to prevent fire spread it must be demonstrated that the barrier is complete over its entire area and that openings have been suitably protected. For active control measures such as automatic and manual suppression systems, the completeness of an installation requires covering two points. Firstly, it should be demonstrated that the control measure covers the entire area of the hazard. Secondly, the analysis should show that the measure includes the means to detect fire and bring about action for its suppression. One tool available for evaluating the completeness of a control measure is the NFPA Decision Tree[7] (See Figure A-4 of Appendix A).

To promote confidence in the control measure, the fire hazard report should discuss both quality and reliability. Quality can be demonstrated by showing that:

1. active control measures are installed in accordance with the appropriate installation standard referenced in report Volume 1 Section F-2 and a comprehensive training program with regular drills are in place for manual fire control measures,
2. passive control measures are installed according to manufacturers' recommendations for assemblies passing standard fire tests (as described in Volume 1 Section F-2 of this report), and
3. administrative controls are documented, procedures for follow-up exist, and audits of controls are completed. (Examples of these programme elements are included in report Volume 1 Section F-3).

Whenever possible a reliability study should be made based on historical data or formalized evaluation procedures.[8] Examples of historical data available for various control measures can be found in Volume 1 Section F of this report.

2.1.2 Control Measures as a Source of Damaging Agents

Active control measures may present a potential source of danger to the safe operation of a nuclear power plant (eg. water spray on emergency power system). A fire hazard analysis should demonstrate the potential impact of these control measures on all exposed items of concern. This may be accomplished by the selection of an appropriate damaging agent descriptor and quantifying its potential change to the environment surrounding an exposed.

2.1.2.1 Damaging Agent Descriptor

The analysis methodology should summarize the cases for harm from control measures which require detailed evaluation. The selection of an appropriate descriptor should be supported by: a synthesis of the analysis approach, the exposed's vulnerability to damage, and details of the exposed's environment. Based on this summary the analysis report should support the selection of a quantifiable descriptor. This descriptor could be selected based on: its chemical composition (eg. strongly acidic which may corrode electrical contacts), its physical state (eg. solid, liquid or gas), or its physical properties (eg. temperature or pressure).

2.1.2.2 Quantify Damage Potential

A hazard analysis report should quantify the change a control measure will make to the environment around the exposed. The discussions of this topic should cover: how and when the control measure activates, the quantity of damaging agent available, and the rate of application in the area of the exposed.

The analysis report should verify a control measure's resulting change to the environment around an exposed by:

1. a reference to a test,
2. calculation, or
3. reference to experience.

2.2 Vulnerability of Exposed

The fire hazard analyst will identify the exposed of interest and cases requiring evaluation. Once identified, the analyst must then establish their vulnerability to damage. This can be accomplished systematically by grouping the exposeds into three main classes: building component, equipment, or personnel. Summaries of the vulnerability of these classes of exposed to damage is available in the literature.[2,9]

2.2.1 Building Component

Under one analysis approach the potential for fire to harm an item or person in an adjacent area is evaluated. In this situation a fire zone boundary is treated as an exposed. This fire zone boundary if often a wall, ceiling or other component of the building. A review of the vulnerability of a building component to damage should cover the potential for exceeding its design objectives. These objectives could include: preventing the ignition of combustibles in a zone and/or preventing temperatures in an adjacent zone from exceeding a specified limit based on equipment or personnel in the area.

The potential for exceeding the fire safety design objective for a building component should be stated in quantifiable terms. The coverage of this topic in the fire hazard analysis report will usually require stating the building component's vulnerability in terms of exceeding its design objective (eg. preventing the non-fire exposed side of a barrier from exceeding a specific temperature or heat flux condition). Coverage of this topic

should also include discussion of the potential for structural failure of the building component under fire conditions. Various means for establishing vulnerability limits for building components are included in Volume 1 Section F-1 of this report.

2.2.2 Equipment

Equipment forms a second class of exposed items of interest and is defined broadly here to include: cables, pipes, and physical systems in the plant. A complete coverage of an exposed's vulnerability should include a listing of the types of equipment components (eg. wiring, metal enclosure, circuit boards), a review of all damaging agents which could affect the various equipment components, and establishing a threshold for damage. In covering the first two items a systematic coverage should be demonstrated. The threshold for damage should be clearly defined in terms of loss of equipment function. This function can be demonstrated from information supplied by the manufacturer, by tests, or by experience, as summarized in Volume 1 Section D of this report.

2.2.3 Personnel

Plant personnel form an additional class of exposed which are of concern in a fire hazard analysis. Discussions of plant personnel as a class of exposed should include all areas where personnel must perform safety functions. Vulnerability of personnel to loss of concentration or conditions which would require evacuation should be established. The threshold values for personnel not being able to perform a given function should be supported by test or experience. Information on these values is readily available from occupational health and safety publications.

2.3 Synthesis

Fire and control measures produce damaging agents which can harm an exposed. Topics which should be covered by a fire hazard

analysis report in quantifying potential damaging agents and establishing the vulnerability of exposed items were discussed previously. To evaluate the impact of the damaging agents on an exposed, a synthesis of the information is required. This synthesis should, for each evaluation, include a comparison of the quantified measures for the damaging agents ability to do harm (i.e. severity descriptors) with the appropriate quantified measures for the exposed's ability to being harmed (i.e. vulnerability descriptors). It should also state if the exposed function would be lost.

The fire hazard analysis report should make conclusions about a fire's ability to affect the safe operation of a nuclear power plant and also relate the conclusions to the overall safety objectives. In doing this the synthesis should summarize the reason for the particular evaluation being performed and should identify the information in the detailed evaluation which could be used in other safety analyses. Coverage of this point should demonstrate a clear picture of the risks associated with the case evaluated and would likely include discussion of: analysis objectives, analysis approach (including its conservativeness), event frequency, all assumptions used, sensitivity of results to input data and conclusions.

Given a comprehensive coverage of each case and a clear synthesis with conclusions for each evaluation, the impact of fire-related damage on nuclear plant safety can be established.

APPENDIX A

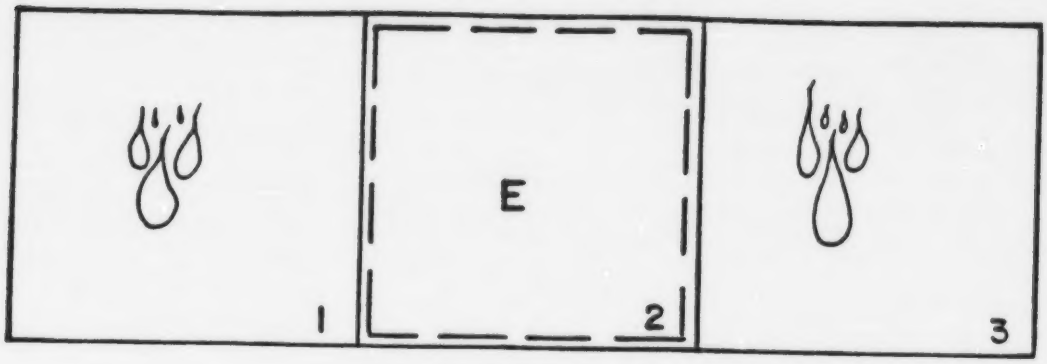


FIGURE A-1: ANALYSIS OF POTENTIAL FOR HARM TO EXPOSED FROM FIRE IN ADJACENT AREA

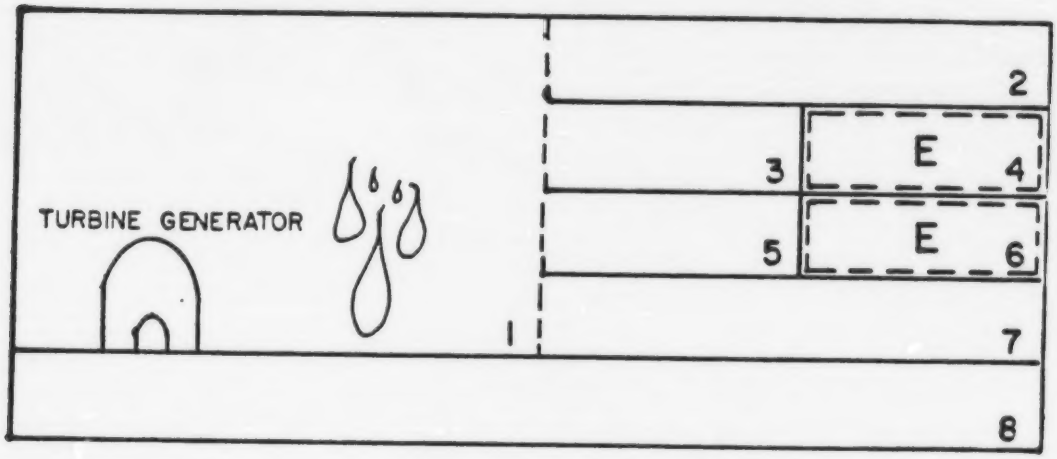
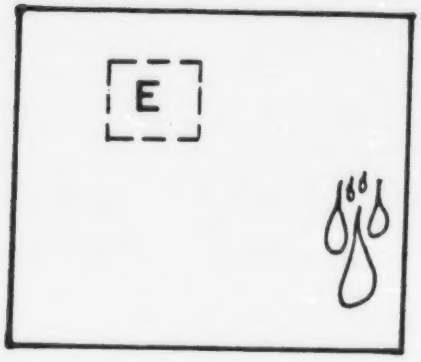


FIGURE A-2: ANALYSIS OF POTENTIAL FOR HARM TO EXPOSED FROM FIRE IN COMMUNICATING SPACE

LEGEND

[E] - EXPOSED ITEM OF INTEREST

2 - DEFINED FIRE AREA OR ZONE



LEGEND

[E] - EXPOSED ITEM OF INTEREST

2 - DEFINED FIRE AREA OR ZONE

FIGURE A-3: ANALYSIS OF POTENTIAL FOR HARM TO EXPOSED FROM FIRE IN SAME AREA

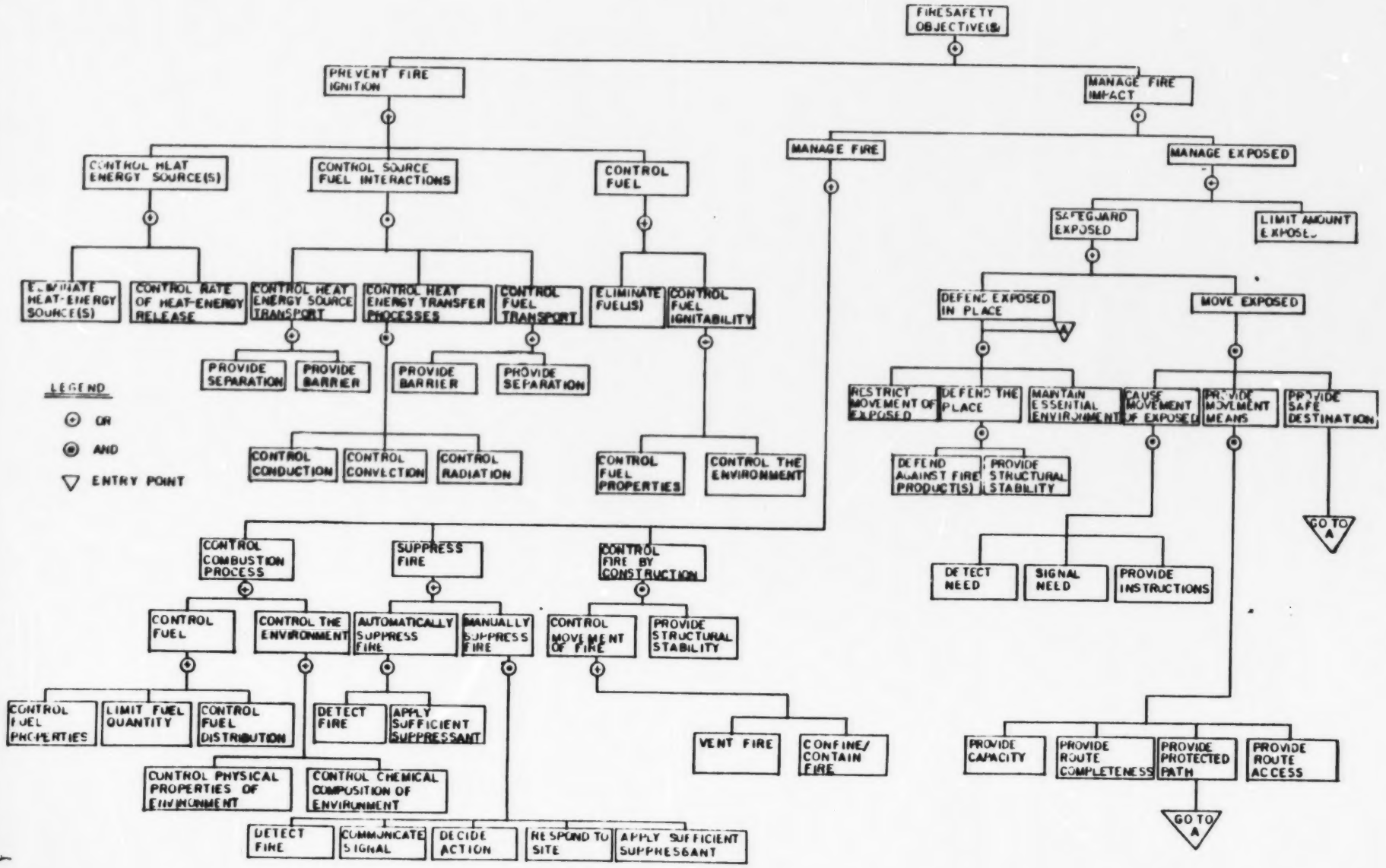


Figure A-4: NFPA Decision Tree[7]

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